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A RESEARCH AGENDA FOR FIRE PROTECTION ENGINEERING

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Notice

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Fire Research Strategies - A Business Rationale

Paul M. Fitzgerald, P.E.
Executive Vice President
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Good afternoon ladies and gentlemen.

It is a great pleasure to be here this afternoon. I have been asked to share with you the rationale why Factory Mutual Research and it's parent company, FM Global believes investing in fundamental fire research is a good investment, especially at this point in time. Before I start, I have to comment that I was on the program planning committee for the workshop. Unfortunately, I had to miss the final meeting when the program and speakers were selected. There is a great lesson in this. Previous to that final meeting, I – along with the other planning committee members – had been enthusiastically volunteering others to give a talk. Miss one meeting and all of a sudden you find yourself being volunteered instead of volunteering someone else.

That said, I'm glad to have this opportunity – and for a good reason. By accepting the invitation to talk about our business rationale for having invested in fire research for well over a century, I found myself thinking back on what we had accomplished over the years and where we planned to go in the future. It was certainly satisfying to review the progress that we all have made and the very positive contribution Factory Mutual Research's efforts have produced. It was also satisfying to reflect on the very positive impact our research efforts have had on our business and for our customers – to say nothing about the public at large. But perhaps the most rewarding aspect of preparing these remarks was the opportunity to think about our plans for future and to do so with an acute focus on the business justification for our very substantial investment in fundamental research.

So, I would like to give you a complete Business Overview if our approach. In doing so, I would like to try and answer three questions. These questions are:

- Why fire research at Factory Mutual Research has been and continues to be extremely valuable as a business strategy?

- The characteristics of business-supported research and the benefits it can bring by using our experience and future plans as an example.

- How we can move ahead with a focused national agenda for fire research using the business model as a guideline.

At the end of our discussion, I would be pleased to answer any questions you may have.

To start, I think it would helpful if I defined what it is that I will call 'research' from here on. The word 'research' is often applied to any activity that involves burning something with a thermocouple or two present. At Factory Mutual Research, we think of our programs of being

one of two types: long term or fundamental research; or short-term testing projects. Let me use the following definitions:

- Definitions

  - Long Term Research: That which has as its objective the development of scientific knowledge from which standardized Testing and solid engineering practice can be developed.

  - Short Term Projects and Testing: Research directed toward resolving a few – often only one – specific problems or issues.

These two approaches – both quite valid depending on the needs – have very different characteristics as it pertains to length of the effort, commitment and perhaps most significantly, uncertainty of payback. Let me characterize long and short term research this way:

- Long Term Research: Is characterized by prolonged investment often over many years. Failure to achieve desired ends is a common outcome.

- Short Term Projects and Testing: Generally involves a finite time period and well defined expenditures for at least the initial testing period and failure is not an accepted outcome.

From a pure business perspective, it is pretty clear that the chances of payback are better with a short-term, pure testing project. There are certainly better prospects for instant gratification with such efforts and less risk of exceeding budgets for gaining a desired result. Therefore, in any business environment, a researcher such as myself has to understand two basic facts of corporate life about both types of research:

- Long Term Research: Is often criticized by management, investors and even other employees who are interested more in today's financial performance than tomorrow's promises.

- Short Term Projects and Testing: Are usually appreciated more because the results are available and thus it is perceived as creating value in today's market by producing immediate solutions to and resolution of customer problems.

So why would a business invest in long term, fundamental research? It has higher risk. It takes longer. It has uncertain costs? Customers may not appreciate it. Financial markets may not appreciate it. It may not solve an immediate – or even long-range – problem. As I consider the above, I sometimes wonder myself why we should invest in it. But it turns out there is justification for such investments. I think the following would apply to any technical organization but I am sure that it applies to fire research and testing:

- Long Term Research: Despite the uncertainty, risk and time for payback, long term research is the only way in which a technical business can consistently create value for its customers.

- Short Term Projects and Testing: Satisfaction – while often appreciated results are delivered – fades quicker because solutions are usually not flexible enough to permit extension of that knowledge to other applications.

We believe that both kinds of programs are necessary and produce useful results. Certainly, we have engendered a lot of customer satisfaction by being able to quickly resolve a specific problem for them through one to a few empirical tests. In some cases, use of existing empirical databases can enable application of past test results to similar but slightly different problems faced by other customers. In addition, in many cases, a quick test program is the most efficient way to resolve a wide variety of potential problems or issues. And of course, standardized tests allow direct use of information in codes, standards and engineering tools.

By contrast, long range research requires a business to strategize its investment. That's how we got started in fire research. I thought it might be helpful to review why FM Global's predecessor property insurance companies developed a fire research capability, and in particular, why we invested in and committed to fundamental research over 35 years ago.

Our History:

Our investment in research began shortly after the Civil War. Our initial investment was primarily driven by an underwriting concern that a large insured fire loss might break the bank. Remember that at this time, the industrial age was producing bigger factories, construction was largely combustible and conflagrations were not uncommon. Perhaps most significantly, automatic sprinkler development was truly in its infancy. Added to that was the fact that all property insurance contracts were 'Fire Insurance Policies' and even as coverage expanded a bit, the largest losses were still fire losses. Small wonder then, that for over a century, we focused almost entirely on fire and explosion.

Our first 'research' investigation looked into the cause of textile machine fires. After having favorable experience for the first thirty years of our existence, the frequency of fires began to increase. This investigation led to the discovery that the cause was the new use of a very flammable liquid to clean the machine. The flammable liquid was gasoline. At that time, gasoline was considered to be an unimportant waste product of lamp oil refining. While this investigation hardly involved breakthrough technology, we learned two important lessons: first, what the direct cause of the increased fire frequency was which was the objective of the investigation; and second, and definitely more lasting, the understanding that even basic technology could change suddenly and silently, resulting in increased exposures and losses.

In the1870's, we began to evaluate sprinklers to determine if we could recommend them to policyholders. When sprinklers were shown to be an extremely effective tool in limiting fire spread, we began to recommend them to policyholders. Where you have sprinklers, you need water and subsequently, we began to do fundamental research in hydraulics in order to assist in the design of public water supplies. In fact, many of the engineering practices used today to design public water supplies were developed by Factory Mutual engineers in the 1880's and '90s.

As sprinklers and water supplies became more available during the early 1900's and manufacturing technologies widened in scope, we found it wasn't just adequate to hook the sprinkler system up to the water and hope for the best. In addition to the hardware and water supply, we found we needed to know how much water was needed to control a particular fire scenario. Our objective was to develop the ability to design or evaluate sprinkler protection systems for particular customer activities. This resulted in our conducting full-scale fire testing and developing sprinkler and other suppression system for the entire family of industrial occupancies. We also instituted the study of losses to determine what the actual sprinkler system had discharged in controlling fires both successfully and not so successfully.

Following World War II, storage occupancies became a particular problem. Both loss experience and individual test results demonstrated that a typical warehouse with wall-to-wall combustibles and ever increasing storage heights presented an extremely challenging occupancy. Working with the industry over the next two decades, we developed several sprinklers – including the standard spray sprinkler – designed with an eye for protecting storage occupancies. With the need to build ever increasing larger fuel arrays to evaluate this protection, however, we also discovered that full-scale testing was becoming increasingly more expensive.

In 1963, with the immense help and guidance of Professor Howard Emmons, the Board of Directors of Factory Mutual Research approved the concept of investing in fundamental research directed at understanding the enormously complex issue of fire. The following year we started a fundamental fire research group housed at the then National Bureau of Standards. With this change, much of our large-scale fire testing began to change from being specifically geared to an individual solution to more or less proving (or disproving – this knife cuts both ways) a scientifically developed concept.

Has It Been It Worth It?

Defining the value of research has always been a dilemma for those of us who believe in it and believe that any company that uses or requires a technology to succeed. Recently, the National Science Foundation undertook a survey of corporations to determine what, if anything, were the drivers in their research and development work.[1] This review discovered six predominant drivers why corporations do fundamental research. They were

- To Generate New Sources of Wealth
- A Corporation's Technology Depends On the Science Behind It
- It Improves the Recruiting of Talented, Creative Staff Throughout the Organization
- It Can Lead To or At Least Create the Promise of Great Discoveries of Proprietary Value
- It Helps the Corporation Benefit From the Spillover From the Technology Revolution
- At the End of the Day, Research Is Perceived to Pay Off

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[1] Hicks, Diana; National Science Foundation Contract No. SRS-99617459 Published by the Industrial Research Institute, Inc. 0895-63-8/99, (1999)

Time only permits discussion of four of these areas. The two I won't dwell on are 'Improves Recruiting' and 'Great Discoveries of Proprietary Value'. Certainly the existence of an effective, long-term research program is a major attraction when recruiting top quality technical people. Our technical employees take great pride on the achievements of the organization and they communicate that to others. As for making discoveries of great proprietary value, the kind of information that Factory Mutual Research produces is only of value when it used in engineering applications. That means the information has to be transferred to others in the form of advice, reports and proposals to Codes and Standards bodies. Thus, the output from our proprietary research cannot remain proprietary for long.

The other areas are fertile, however, and have and continue to contribute to our business success.

1. To Generate New Sources of Wealth: This should seem to be an obvious output of any fundamental research. In today's world, however, this vision is significantly different from most current corporate initiatives. Downsizing, re-engineering, mergers, knowledge management and most of the other current corporate hot buttons are predominantly geared toward extracting maximum value from the products and services in provided by the existing business. Long-term research often doesn't provide a financial payback for years.

   While it is common to think of 'wealth' as increased profits and market value, I would also offer up the paradigm that knowledge is also a measurable form of wealth. Using that knowledge in the conduct of the enterprise's business should result in improved products or services and especially, produce improved decision making for the enterprise. This advantage can be used many ways:

   - To manage enterprise risk far more effectively;
   - To be able to anticipate the competition and therefore move more proactively than they can move;
   - To be more effective in strategic planning in all technical areas;
   - To be anticipate a customer's changing needs; and, very importantly; and
   - To be able to spread this increased knowledge into other areas of the enterprise's business and enhance operations in unaligned areas.

   In our case, having a research capability has brought us in contact with materials, products, technologies and affiliations that would not exist otherwise. As a result, we can and have been able to achieve these advantages in many situations.

2. Technology Depends on Science: Long-term research is invariably involved in searching for scientific truths to allow for wide understanding of physical phenomena and proper application of the results. As we have seen, however, testing and problem-solving research is interested predominantly in an immediate, usually very limited result that addresses a specific problem or issue. Short-term research is necessary, of course, and the results from tests and experiments can provide insight into the fundamental nature of a particular problem. Despite its value, however, total reliance on research that does not deal with the fundamental nature of the problem is inadequate. There are at least three major shortfalls with an approach based on point-by-point test results:

First, it is a very expensive way to do research. Test-by-test research obviously involves an attempt to draw an empirical circle around an objective or problem by having a number of data points (and possibly a large number of such points) to provide a level of confidence in the final 'result'. This can be costly – and especially so in fire research where fire dynamics often dictates testing at larger scale. Unless there is a good understanding of where a program is going, I can testify that the costs for such programs can be prohibitive.

Second, running repetitive experiments varying one or two conditions per experiment takes time. In fact, while one of the leading raps against fundamental research is time to completion, once completed it usually leads to a more universal application of results. Empirical research programs are not so blessed. A generalized result may not respond to future changes in a particular technology. Certainly our nation's fire record has ample evidence of a major losses which have occurred because of a change – often perceived to be minor – in a building or specific occupancy.

Third, if a scientific solution does not exist, the danger of there being more gaps in application technology increases. This is probably the most telling argument. We cannot afford such gaps to develop if life and property losses are to continue to be minimized.

Hick's NSF study also provided some interesting data on the relationship of science and technology in the citations in patent applications. Historically, most 'prior art' citations were to previous patents. In the last decade, however, an increasing percentage of patent citations referred to the scientific literature and not prior art. For example, in this most revealing exercise of technology development, the growth of prior art references to scientific publications is increasing at a rate of over three times that of references to patents. While part of this increase is no doubt attributable to better data base searches and to Patent Office diligence in assuring full disclosure, it nevertheless highlights that fundamental research is increasingly finding it's way into application.

3. Spillover From the Technological Revolution: This finding is based on the precept that most of the knowledge gained doing long range research is not generated by the business doing the research. Consider that in 1998, the National Science Board estimated that about $50B of research was done and made available to the public.[2] This research includes not only the research done by the government, but also by universities, public grantees and non-profit organizations like Factory Mutual Research. In fact, only about 8% of the papers published in the scientific literature during last year were from corporate research scientists.

   Taking advantage from the work done by others is critical. Furthermore, an organization that does not engage in fundamental, long-range research may find themselves at a serious disadvantage to those that do. There are several reasons for this. For example, a non-research organization:

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[2] National Science Board, *Science & Engineering Indicators – 1998*; National Science Foundation, Arlington VA, 1998 (NSB 98-1).

- Would not have the scientists who as a matter of their work tend to find and bring valuable information, data and knowledge into the organization.

- Even if they come by valuable research information, they would not have the skilled staff that a research organization has to appreciate it's value and importance. In other words, there would be a very high probability that the information would go unused or even worse, be used inappropriately thereby damaging the organization's results.

- Almost certainly, they would not be able spin the information and knowledge they have into new products and services.

- Finally, they would probably not have access to networks of research organizations and individuals who could be of assistance in helping solve problems and plan future improvements in their product and service base.

Of all of the reasons for doing long term research, this may be the single greatest advantage to a business. It is becoming increasingly more difficult to make major technological breakthroughs. Instead, most research outputs are incremental gains rather than giant leaps for mankind. Because all businesses have limitations in human and financial resources, knowledge must be obtained from all sources and used appropriately. This is where the 'spillover' concept is critical. In a knowledge age and especially an age that is increasingly technical, being able to access the world's available knowledge and use it for the business competitive advantage is essential for long-term survival in many – if not all industries – if the organization is to survive.

4. Research Pays: At the end of the day, there has to be a payback to a business for its investment in research – and especially long-term research. Unfortunately, proving that long-term research pays is difficult. Intuitively, one would think that investing in a solid, strategically aligned research effort would always be in the best interests of the business. If we are asked for examples companies where we most think this is true, it is likely that we would think of the high tech, pharmaceutical or biotech industries as proof. On the other hand, with industries such as basic metals, electronics or diversified chemicals – all of which experienced technology breakthroughs decades ago – it is more difficult to conceive of such advantages.

   Certainly there is evidence and data (albeit a lot of it is several decades old) that suggests research 'pays'. In the high tech industry, surveys of patents and scientific reputation of companies indicated that the tighter the linkage between research and market value, the better the average return on a stock investment. Specialty chemical companies also have a significant – ~25% – better market-to-book value where this tight link of science-to-patent exists than in companies in which the link is weak. Even accountants are paying attention to research as they attempt to 'value' knowledge capital to include it on their books. Assuming that all of these valuations are classified as assets, we might soon have arguments as to the value of research.

The above are fun to talk about and compare one to the other. On the other hand, financial and competitive measures are just one way to prove 'research pays'. Today, organizations like

Factory Mutual Research are evaluating other ways in which it may pay. The most commonly used terminology in establishing and managing research program portfolios for specific targets is called 'value creation'. Using value creation, the research organization attempts to emphasize value, not 'beating the competition' or 'improving shareholder value'. It tends to focus more on the customer by bringing new and superior products or services to them, even if increased revenues aren't huge. In many cases, small advances can result in quantum leaps in perceived value and that can lead to one of the most critically sought after objectives of any business – namely, customer loyalty.

The value equation should be brought to bear on the next generation fire research. We don't have 'buyers' in the traditional sense of the word but we do have 'customers'. In fact, we have a monster customer base – it's called the general public. This customer base will be looking for us to provide buildings and other occupied spaces that are economic, attractive, durable and yes, safer from fire. If we can achieve this, we will provide enormous value to this critically important constituency and that will build the incentive for investment into fundamental fire research.

Factory Mutual Research's Strategy

Long-term research has to be directed at creating either financial or customer value for an organization. The best chance the organization has that its research will be successful is if it is tightly tied to the overall corporate strategy of the enterprise. And that is certainly true for us.

In many ways, we are at one of those watershed periods where a company has to strategically adapt to a new world. There have been many recent changes in our business. For example, traditional fire insurance policies are now more accurately described as 'Property Insurance' policies because they routinely cover such perils as wind, flood, earth movement, etc. Fire and explosion, once 80% of our loss experience, are as likely to be less than 40%. Clearly, if this is where the dollars are being lost, Factory Mutual Research must strategically widen its area of research interest if there is inadequate work being done in these areas.

We are in the process of broadening our research into four areas:

- Fire and Explosion Protection: This has long been our focus and it will continue to be a strategically critical research area. In other words, while we may look into other areas, we will still continue our work in this crucial area.

- Materials: Increasingly, we are finding newer materials being used in many applications replacing materials where we had a strong legacy of knowledge about those materials. Where once we would have only focused on flammability, our research will know consider all of it's properties – mechanical, resistance to corrosion, strength as well as flammability.

- Structures: There have been dramatic changes is the design of most industrial and commercial buildings. The many advantages in terms of cost, functionality and speed of construction – to say nothing about performance-based design – make it likely change will continue well into the 21st century. The performance of some of these buildings against the perils of wind, earth movement and other extraordinary loadings has not been

adequately researched. We are looking into these areas and building relationships to take advantage of as much prior knowledge as possible.

- Reliability Engineering: At the heart of most manufacturing process lies some form of control systems. These systems often have well-defined technical data on such as things as the failure rate of components. Failure of a component doesn't necessarily define the failure of a system. On the other hand, proper operation of a system doesn't necessarily guarantee an incident could not occur, especially when human element is factored in. In either case, the consequence of an event given certain failure modes also has to be defined and our research is attempting to develop criteria that can be used by system manufacturers and designers as well as risk analysts.

Suggestions for Moving Forward

I believe that the process Factory Mutual Research is currently using – a process that parallels in many ways how other organizations conduct research – can also be used as a guide to develop a national research strategy needed to develop the knowledge, tools and information necessary to support quality performance-based Codes and Standards. For example:

- Follow A Typical Business Model: Develop an overall strategy – even a full-blown Strategic Plan – that identifies realistic visions and very specific goals that everyone – buyer, designer, insurer, fire service and manufacturer – can buy into. We have tried to do this before in the 80's and 90's but to a large extent, progress has been more on an individual researcher than coordinated basis. This strategy has to be specific and down to earth so that organizations that do research can understand and bite off that they may be best qualified to do or could contribute to.

  In addition to very specific goals, the strategy should identify the infrastructure needed to support the gradual emergence of performance-based codes and standards. Key among the infrastructure needs is to agree on a common language in for data management, engineering models and test protocols. If this very fundamental foundation is not built, we run a very real risk of creating a modern-day Tower of Babel. Progress will be definitely slowed down while technical arguments rage over which tests are the best or the most accurate or the most appropriate for this material or that application. If you don't think this will happen, then you haven't been a student of the twenty-year history of debates within the fire research community over different protocols and technologies. At the core of many of these are classic apples and oranges comparisons of very different end results.

- Do Fundamental Research: As I discussed earlier, in our work, we approach our research from a fundamental view. We want understand the basic underlying science of a particular investigation. In the end, this leads to lower overall cost, improved technology and a better understanding of where to go next. It also increases the chances of doing the research once because we would have a better chance of doing it right. This rationale has to be applied here. We have come a long way in fire research in the past 50 years but the world does not stand still. We need better understanding of the science of flammability

and suppression if we expect manufacturers and fire protection companies to develop safer materials and better protection systems.

To accomplish this, we need to reinforce the scientific peer review processes in place today. Because of the scarce number of truly qualified researchers in North America, we need to involve all global scientists in an objective network of competent reviewers. The review should not only be of scientific papers but also proposed test instruments and new protocols if these are to be used in any Code or Standard application. In short, to be successful, we need to establish an infrastructure that has the highest level of integrity and does not allow for the introduction of substandard tests or protocols that meet a particular vested interest's needs.

- Consciously Strategize to Create 'Spillover': Although we didn't define it this way at the outset of launching our new programs, Factory Mutual Research certainly tried to create as much 'Spillover' as possible to accelerate the speed and minimize any duplication in the work that we have done. We have established liaisons with other research centers focused on Structures (wind, earthquake), Materials (flammability, corrosion, restoration of property) and Reliability Engineering. On reflection, I would say that in many ways we did the same thing in the mid-60's when we worked closely with NBS and Dr. Emmons on their research while at the same time starting our own fire research program. Fire research crosses most scientific and engineering disciplines and in this area in particular, I would posit that there are many opportunities for synergy and 'spillover' from other disciplines to ours and they should be tapped.

- Establish Networks of Research Institutions and Keep Them Well Advised of What Is Needed and What Has Been Done: Realistically we need to face one very limited fact of life and that is that no private research organization will drop what it is doing to support a national effort. I will candidly admit that Factory Mutual Research will not and cannot afford to do that no matter how noble a particular national research initiative may be. That said, however, it may be that if we are aware of other programs and data needs, there may be opportunities to piggyback additional instrumentation or collect additional data points on a program we are conducting and provide that to other investigators with minimal impact on our cost or cycle time. By networking all researchers, we will also minimize the chances of duplication and possibly promote better cooperation in the development of standardized instruments, data definitions and test protocols. There are models for this level of cooperation in medical research and these models can serve as a basis for establishing similar networks for fire research.

- Communicate, Communicate and Communicate: Finally, let's keep in touch with each other. Over the years I have attended many symposia or conferences and when it is over, we all run back to our work places until it is time for the next symposia or conference where we wonder what happened to all the great ideas from the last one. I think that networking, establishing 'Centers of Excellence' if that's the right approach and peer review systems can all contribute to promoting better cooperation and exchanges among researchers and practitioners but there has to be a continuous day-to-day forum as well. Every business strategy includes a communication strategy. Very clearly, we need to devise one as well.

Summary:

I want to thank you again for the opportunity to be here today and share with you some of the background why Factory Mutual Research exists and how we go about defining and prioritizing our research. While we are sort of unique in what we choose to research into, we are clearly not unique in the way we approach it. I think that our approach – in fact, the approach of most businesses – can be adapted to a national approach. If we are successful in launching such an effort, we stand ready to participate as we seek to improve the fire safety of future generations of buildings and the people who occupy them.